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Development of an Environmental Monitoring Technique Using Synchronous Excitation (SE) Fluorescence Spectroscopy

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16. ABSTRACT

Environmental monitoring of discharge plumes (surface and groundwater) and effluents generally involves extensive analyses for specific analytes. This monitoring frequently employs GC, GC/MS, ICAP or AA techniques. These techniques usually require extraction procedures followed by analyses for specific analytes. When monitoring complex mixtures, these procedures can become more difficult, time consuming, prone to analytical and interpretational error and limited by analytical thresholds to the ppb and ppm range. When environmental discharges occur, the dilution process exacerbates analytical problems by attenuating compounds through the environmental media and lowering concentrations. An alternative/supportive technique in these situations is the use of SE fluorescence spectroscopy. This technique can be used for fingerprinting effluents and contaminant mixtures in the ppt range and can be used to evaluate the presence of mixtures (e.g. effluents) and dilution plumes.

An SE fluorescence technique was developed specifically for monitoring effluent from a facility manufacturing a variety of dyes and ancillary products. Prior to discharge, the effluent was treated in a biological and charcoal (PAC) waste treatment system. The effects of sampling (composite, grab), sample storage, fluorescence properties of the effluent (spectral fingerprint) and fluorescence characteristics of the effluent in ambient waters was determined. Consequently, a method was established which "fingerprints" effluent at dilutions of 1:1000, can identify effluent at dilutions of 1:4000, and has fingerprinted similar source material in a rivershed adjacent to the site. This rapid approach can be used to fingerprint and monitor a variety of environmental discharges of plumes when appropriate contaminants are present.

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DEVELOPMENT OF AN ENVIRONMENTAL MONITORING TECHNIQUE USING SYNCHRONOUS EXCITATION (SE) FLUORESCENCE SPECTROSCOPY

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ABSTRACT

Environmental monitoring of discharge plumes (surface and groundwater) and effluents generally involves extensive analyses for specific analytes. This monitoring frequently employs GC, GC/MS, ICAP or AA techniques. These techniques usually require extraction procedures followed by analyses for specific analytes. When monitoring complex mixtures, these procedures can become more difficult, time consuming, prone to analytical and interpretational error and limited by analytical thresholds to the ppb and ppm range. When environmental discharges occur, the dilution process exacerbates analytical problems by attenuating compounds through the environmental media and lowering concentrations. An alternative/supportive technique in these situations is the use of SE fluorescence spectroscopy. This technique can be used for fingerprinting effluents and contaminant mixtures in the ppt range and can be used to evaluate the presence of mixtures (e.g. effluents) and dilution plumes.

An SE fluorescence technique was developed specifically for monitoring effluent from a facility manufacturing a variety of dyes and ancillary products. Prior to discharge, the effluent was treated in a biological and charcoal (PAC) waste treatment system. The effects of sampling (composite, grab), sample storage, fluorescence properties of the effluent (spectral fingerprint) and fluorescence characteristics of the effluent in ambient waters was determined. Consequently, a method was established which "fingerprints" effluent at dilutions of 1:1000, can identify effluent at dilutions of 1:4000, and has fingerprinted similar source material in a riversbed adjacent to the site. This rapid sample approach can be used to fingerprint and monitor a variety of environmental discharges or plumes when appropriate contaminants are present.

INTRODUCTION

The State of New Jersey, Department of Environmental Protection (N.J.DEP) administers industrial discharge permits through the State NJPDES program. One of the permitted facilities manufactures a variety of dyes and ancillary products and employs

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an ocean outfall. Concerns were expressed by the public about the environmental release of effluent from the facility. Consequently, it was necessary to develop a sensitive, specific method for the effluents identification and quantitation. Earlier studies indicated that the effluent contained various fluorescing components including azo dye and aniline derivatives. Therefore, the use of fluorescence spectroscopy was evaluated for monitoring the industrial effluent.

The study was established in several phases. The first phase of the study determined the fluorescence properties of the effluent to ascertain whether a characteristic spectal fingerprint was obtainable and whether a simple, rapid method based on Synchronous Excitation (SE) Fluorescence could be used to monitor the discharge. During this phase, the effects of sampling (composite vs. grab), sample storage, and the effects of dilution in lab and sea water were determined.

During the course of the study, Rhodamine WT was added to the industrial discharge as part of a hydrological study to determine the dilution characteristics of the waste and its fate. Consequently, the second phase of the study evaluated the use of Synchronous Excitation Fluorescence Spectroscopy to monitor the industrial discharge for rhodamine dye tissues.

The final phase of the study has continued to evaluate the SE fluorescence method established with samples taken a year later and in sea water dilutions.

WHY FLUORESCENCE SPECTROSCOPY WAS CHOSEN

Ultraviolet fluorescence spectroscopy is a useful analytical technique for the measurement of many hazardous materials. It is exceptionally sensitive and often more specific than other spectroscopic methods such as ultraviolet, visible, and infrared absorption techniques. Kullbom, et. al.[1], used fluorescence spectroscopy to analyze for phenols and lignins in water. Other investigators[2-6] used it to measure petroleum and non-petroleum hydrocarbons in water. Some of the later investigators[2,3,5,6], extracted the toxicants from water with solvents prior to measurement. Kullbom, et. al[1] and Frank[4], measured toxicants directly in water. All of these investigators used conventional single wavelength excitation (SWE) techniques.

SWE fluorescence spectroscopy is not satisfactory for in-situ measurements of hazardous materials in water. Spectra derived from use of the SWE technique are distorted by Rayleigh-Tyndall and Raman scatter radiations, especially when these spectra are

obtained from samples containing only mg/l of toxicants. Consequently, the use of "Synchronous Excitation" (SE) fluorescence spectroscopy for rapid in-situ quantification of hazardous materials in water has been demonstrated by several authors[7,8] to yield substantially improved spectral resolution.

The authors demonstrate that this technique also yields spectra free of Rayleigh-Tyndall and Raman scatter when used for in-situ quantification of hazardous materials in water.

Differences between SWE procedures and the SE technique and the advantages of the latter for in-situ quantification of hazardous materials in water are discussed within the context of a three dimensional coordinate system. This system was previously described by Frank[9], and Frank and Gruenfeld[10]. Three interdependent variables that are inherent to fluorescence spectroscopy are used as axes: (1) excitation wavelength (x), (2) emission wavelength (y), and (3) fluorescence intensity (z). Within this context, the fluorescence properties of hazardous materials are viewed as "total fluorescence spectra" and the SE and SWE fluorescence approaches are readily compared.

A three dimensional total spectrum of a compound that resembles a mountainous region is shown in Figure 1. The two mountain peaks (solid lines) are in fact the fluorescence maxima of this compound. SWE spectra are two dimensional slices through the three dimensional spectrum, parallel to the (y) axis. According to Lloyd[7], such spectra provide only limited useful information. SE fluorescence spectra, however, are slices oriented at a 45° angle to the (x) and (y) axes and often yield more useful information.

The ability of SE fluorescence spectroscopy to avoid Rayleigh-Tyndall and Raman scatter distortions of spectral profiles is demonstrated within the context of the three dimensional coordinate system. The combined effect of these scattering phenomena can be viewed as resembling a three dimensional "interference wedge" that bisects total-fluorescence spectra (Figure 2). Although this interference wedge causes detrimental spectral distoritions when using SWE techniques, it can be avoided by using the SE procedures (Figure 3). Rayleigh-Tyndall (reflected) scatter radiation is especially troublesome when measuring natural waters that contain suspended particulates. Spectra obtained with the SE and SWE procedures are contrasted in Figure 4, a synthetically prepared sample of phenol in blackish marsh water containing suspended particulates was measured. This example illustrates the obvious advantage of the SE technique, i.e., its elimination of scatter interferences.

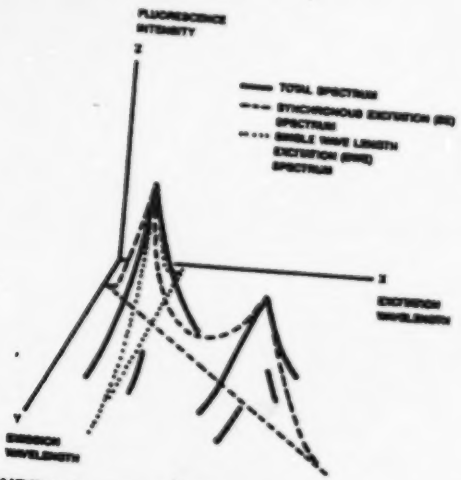

FIGURE 1: Comparison of SE, SWE and Total Fluorescence Spectra Within the Context of the Three Dimensional Co-ordinate System

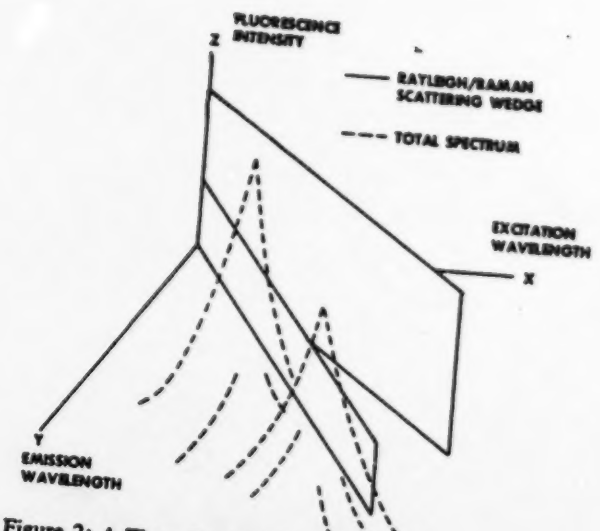

Figure 2: A Three Dimensional Presentation of a Rayleigh-Tyndall/Raman Radiation "Scattering Wedge", Superimposed on a Total Fluorescence Spectrum of a Hazardous Material

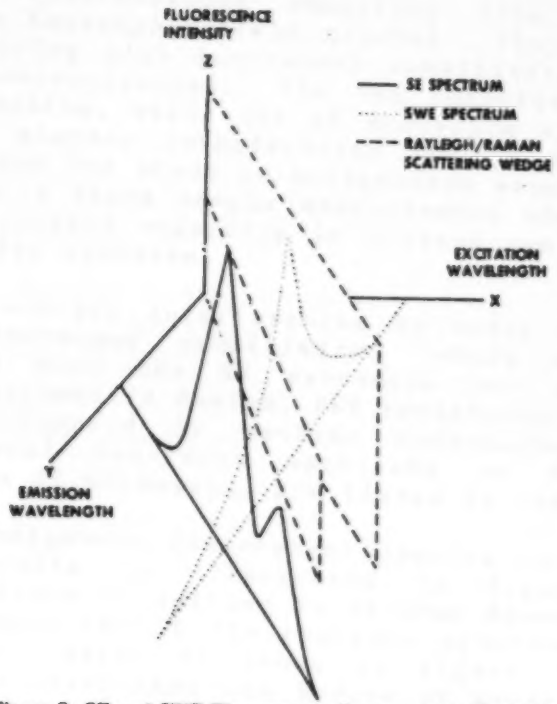

Figure 3: SE and SWE Fluorescence Spectra, and a Rayleigh-Tyndall/Raman "Scattering Wedge" (This Demonstrates that the Scattering Wedge is Readily Avoided by Use of the SE Technique)

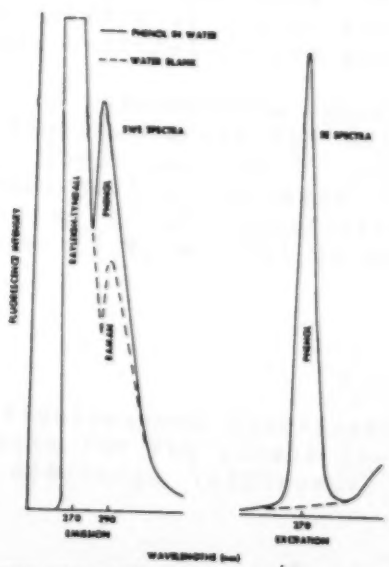

Figure 4: SE and SWE Spectra of Phenol "Spiked" into Water Obtained from a Marsh in Sayreville, New Jersey (The Water Contains Suspended Colloidal Particulates. Phenol Concentration is 1 mcl/l)

Raman scatter interferences emanating from water are less pronounced than Rayleigh-Tyndall scatter. They become apparent, however, when using high instrument sensitivities for measuring low toxicant concentrations. The SWE technique fails to avoid this scatter problem, while the SE procedure avoids it readily. Elimination of scatter interferences by the SE procedure also minimizes the need for blank or backgrounds sample analyses. SWE techniques require blank sample measurements whenever instrument parameters are changed resulting in a large number of additional and time consuming analyses.

Elimination of scatter interferences by using the SE procedure also permits increased sensitivity. While actual detection limits obtained with the SE procedure are determined by a fluorescence instrument's design, SWE techniques detection limits are severly influenced by scatter interferences. Detection limits of several hazardous materials in distilled water, determined by the SE technique, are listed in Table 1.

The effect of indigenous fluorescent species in natural waters, on analysis results is illustrated in Figure 5. The SE fluorescence spectrum of aniline in Raritan River water is shown in Figure 5a; while the SE fluorescence spectrum of aniline in Arthur Kill River water is shown in Figure 5b. These five represent heavily trafficked and bodies of water in New Jersey. The SE fluorescence spectrum of aniline in distilled water is shown in Figure 5c. The spectrum of the latter figure was used as standard for quantifying aniline in Figures 5a and 5b; recoveries were 96% and 94% respectively. In effect, the aniline in distilled water solution was used as the standard for quantifying the aniline content of synthetically prepared samples containing this hazardous material in two polluted waters.

In addition, the use of synchronous excitation fluorescence spectroscopy has also been preferred for monitoring Dye Tracers in hydrology studies. Andre et. al.[11] points out that this techniques gives a preceptible increase in sensitivity and reduces experimental errors in the qualitative and quantitative determination of Rhodamine (G,B, and WT) in water samples.

METHODS

1. OVERVIEW

Synchronous Excitation Fluorescence Spectroscopy (SEFS) was used as the analytical procedure for the direct in-situ measurement of fluorescing industrial discharge (effluents) and Rhodamine Dye

Tracer in Ocean Surf Water Samples. The SEFS method was also used as an analytical procedure for direct in-situ screening of hazardous materials in water and includes the following:

2. CAUTIONS AND LIMITATIONS:

2.1 All glassware must be rinsed (three times) with carbon filtered, distilled water and air dried prior to use.

2.2 Preparation of standards and samples should be performed inside a fume hood to minimize exposure of laboratory personnel to hazardous substances.

2.3 All measurements of standard and sample solutions and solvent blank must be conducted under identical instrumental conditions.

2.4 The instrument recorder baseline should be deflected at least ten percent of full scale to avoid erroneous zero measurements.

3. APPARATUS AND REAGENTS:

3.1 APPARATUS

1. Beaker, 50 ml
2. Fluorescence spectrophotometer equipped with dual monochromators for synchronous measurement (Perkin-Elmer Model MPF-44B)
3. Micropipets, digital adjust (Scientific manufacturing Industries, or equivalent)
4. Quartz cuvette
5. Volumetric flasks, assorted volumes

3.2 REAGENTS

1. Distilled water, carbon filtered
2. Pure material for standard preparation

4. PROCEDURES:

4.1 STANDARD PREPARATION

1. Place 90 ml of distilled water into a 100 ml volumetric flask.
2. Weigh 20 mg of the standard material and quantitatively transfer the material to the volumetric flask.
3. Stopper the first and invert repeatedly to ensure uniform mixing.

TABLE I. DETECTION LIMITS FOR SEVERAL HAZARDOUS MATERIALS IN WATER

Hazardous Material	Detection Limit (ppm)
Aniline	0.005
O-Cresol	0.1
Dodecyl Benzene Sulfonic Acid	0.1
Naphthalene	0.02
Naphthenic Acids	0.1
Phenol	0.01
Quinoline	0.005
Resorcinol	0.02
Styrene	0.005
Toluene	0.1
Xylene	0.1
Xylenol	0.1

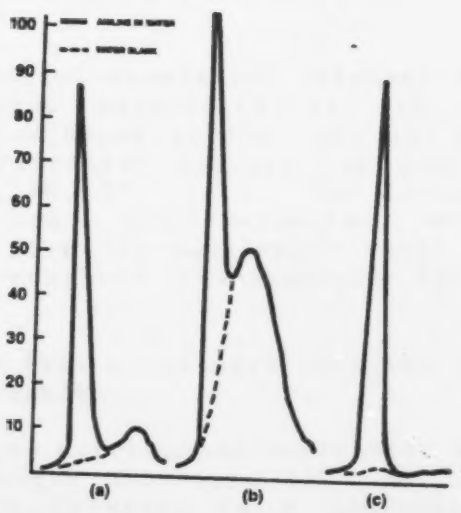

FIGURE 5: SE Spectra of Aniline "Spiked" into River Waters (A) and (B) and Distilled Water (C). Aniline in Water Concentration is 1 mcl/l. The Waters used to Obtain (A) and (B) were Collected from the Raritan and Arthur Kill Rivers in New Jersey, Respectively. Both Rivers are Subject to Heavy Marine Traffic and Chronic Pollution from Petroleum and Industrial Chemicals

4. Fill the volumetric flask to the fiducial mark with water; the concentration of the stock solution is 200 mg/L.
5. By dilution, prepare a calibration solution and establish a calibration range incorporating the expected concentration of the samples.

4.2. SAMPLE PREPARATION

1. Samples must be stored in glass bottles and refrigerated prior to analysis.
2. Direct in-situ measurement of hazardous materials precludes the need for extensive sample preparation preceeding fluorescence analysis.

4.3 FLUORESCENCE ANALYSIS

1. Use the following instrumental conditions:

Excitation wavelength	200 nm
*Initial wavelength interval (Δ)	20 nm
Initial emission wavelength	200 nm
Excitation slit width	10 nm
Emission slit width	10 nm
Wavelength drive	Excitation
Mode	Dual
Amplifier dynode voltage	Ratio
Recorder power	Servo

*NOTE: The initial wavelength interval of 20 nm requires an initial emission wavelength of 220 nm. The emission wavelength is adjusted to 230 nm, 240 nm, etc., to record synchronous excitation spectra for each set of wavelength intervals (30, 40, 50, etc.). The excitation monochromator is scanned in synchronization with the emission monochromator over the wavelength range of 200 nm - 500 nm to obtain a complete fluorescence spectrum of the test material.

2. Select the best wavelength interval to yield optimum spectral results.

1. Observe the synchronous excitation spectra for each set of wavelength intervals (20, 30...., 100). The best wavelength interval is a compromise between maximum fluorescence intensity and optimum peak resolution.
2. Establish the best wavelength interval and record the synchronous excitation spectra of the calibration solution and calibration standards under these conditions.

3. Record the synchronous excitation spectra of the solvent blank (distilled water), the sample solution(s), and the sample blank (if available) under identical instrumental conditions.
4. Assure instrument stability by scanning the calibration solution and solvent blank following each fifth sample measurement.

DISCUSSION/RESULTS

PHASE I

The primary objective in Phase I was to determine whether a simple and rapid method based on SEFS could be used for monitoring industrial discharge (effluent) in ocean water without the addition of dye tracers. The approach was based on the assumption that the fluorescing components in the industrial discharge would provide a spectral fingerprint traceable to the source in ocean water. Furthermore, it was anticipated that the fluorescence fingerprint could be used to follow the migration of chemical discharge plumes from the source and determine its ultimate fate along the New Jersey shore.

COMPARISON OF SINGLE WAVELENGTH EXCITATION AND SEFS

Figure 6 illustrates the type of fingerprint obtained by using single wavelength excitation to obtain a fluorescence fingerprint. The first peak in Figure 6 is caused by Rayleigh-Scatter interference in the Single Wavelength excitation spectrum. Also, note the increased spectral resolution (and improved fingerprint pattern) in the SEFS spectrum. Figure 7 showns the same effluent grab sample but the spectrum was obtained using the SEFS method. Note the absence of spectral distortions and interferences in the SEFS spectrum.

Figure 6 illustrates the type of fingerprint obtained by using single wavelength excitation to obtain a fluorescence fingerprint. The first peak in Figure 6 is caused by Rayleigh-Scatter interference in the spectrum. Figure 7 showns the same effluent grab sample but the spectrum was obtained suing the SEFS method. This spectrum exhibits increased spectral resolution and the fingerprint represents a summation of all fluorescing materials under these instrument and effluent conditions. This synchronous fluorescence scan is a reflection of the batch production processes at the plant. Although specific facility production varied over time, a combination of factors - waste treatment system, constrancy of chemical groups (i.e. from dyes, phthalates), low process flow, tended to yield

FIGURE 6. SINGLE WAVELENGTH EXCITATION FLUORESCENCE SPECTRUM OF GRAB 1.

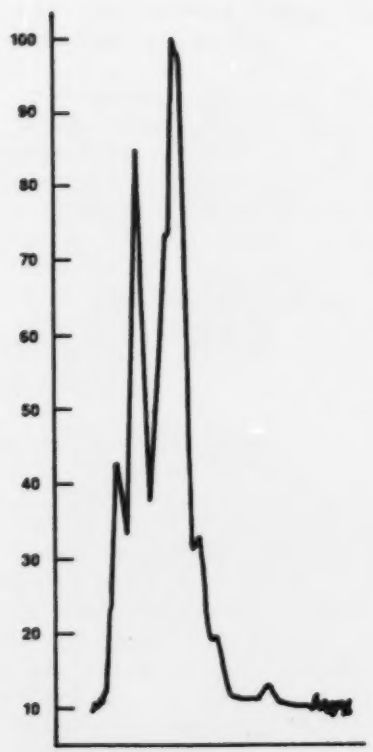

FIGURE 7: SEF spectrum of Grab 1.

similar effluent fluorescence spectra over months of sampling. Results indicated that similar spectra were obtained from composite and grab samples. In addition, samples were unusually stable. With refrigeration and no preservative, similar spectra were obtained almost one year later.

SELECTION OF OPTIMUM WAVELENGTH INTERVAL (DELTA)

Wavelength intervals ranging form 10 to 120 nm were evaluated to determine which interval (delta) yields the optimum spectral resolution for fingerprinting (qualitative analysis) and which delta yields the maximum spectral intensity (quantitative analysis). Figure 8 illustrates that the delta of 20 nm provides the greatest spectral resolution for fingerprinting the industrial discharge of Grab 1. A delta of 80 nm provides the greatest fluorescence intensity for quantitative analysis.

SPECTRA COMPARISON

For samples containing elevated levels of industrial effluent a delta of 20 nm was used to obtain the maximum amount of spectral detail for fingerprinting purposes. To assure that concentration quenching effects did not interfere with the sample spectra most effluent samples were diluted 1 to 10.

The SEFS fingerprint patterns of the effluent appear to be relatively constant, with the same peaks present and minor variations in peak intensity. This is shown in Figure 9 which compares the spectra obtained of samples collected a month apart (Composite/vs. Grab 2). Figure 10 illustrates SEFS fingerprints of effluent sampled over a month later (6/12/86). At this time Rhodamine WT was also added to the effluent as a dye tracer at the source of discharge. The fingerprint of these samples all appear similar, even though sampled at different dates. In addition, the Rhodamine peak does not appear to interfere with the effluent SEFS fingerprint.

The SEFS fingerprinting technique was also applied to samples of swamp water taken from Winding River Park adjacent to the facility. The spectra (Figure 11) indicate the same presence of fluorescence peaks as in the effluent, although the peak height maxima have changed. These Winding River samples represent the fluorescence spectra of material which are presumed to derive from the facility and do not occur naturally in swamp or ground water. (The Winding River sample fluorescence is presumed to derive from the same generic composition of varying concentrations of dyes, phthalates, plasticizers and nitrophenols. These materials are believed to be entering the river through contaminated groundwater).

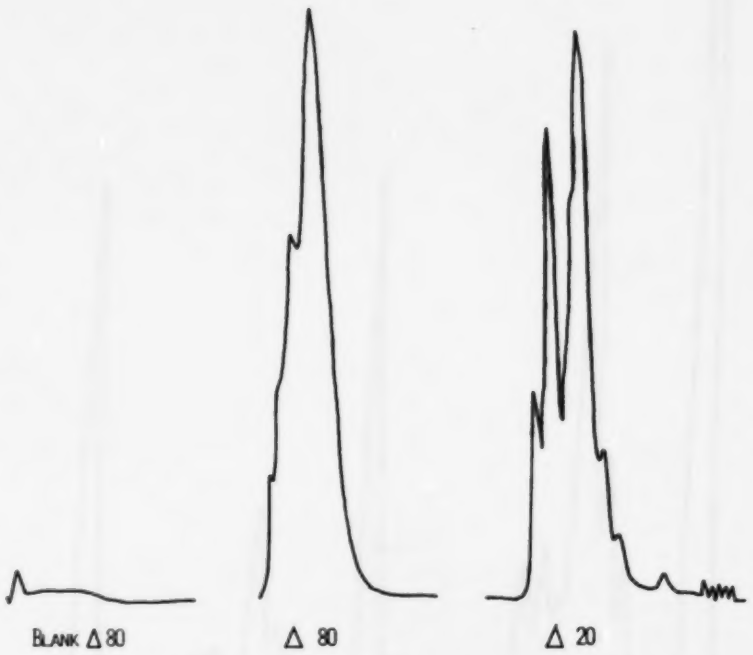

FIGURE 8. COMPARISON OF WAVELENGTH INTERVAL USING SEFS FOR GRAB 1. DELTA 20 NM WAS THE OPTIMUM INTERVAL FOR FINGERPRINTING.

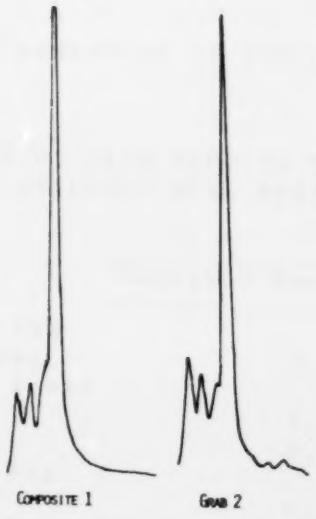

FIGURE 9. SEFS FINGERPRINTS OF EFFLUENT DERIVED FROM A DELTA OF 20 NM. THE COMPOSITE WAS SAMPLED 4/9/86; GRAB 2 WAS SAMPLED 4/28/86

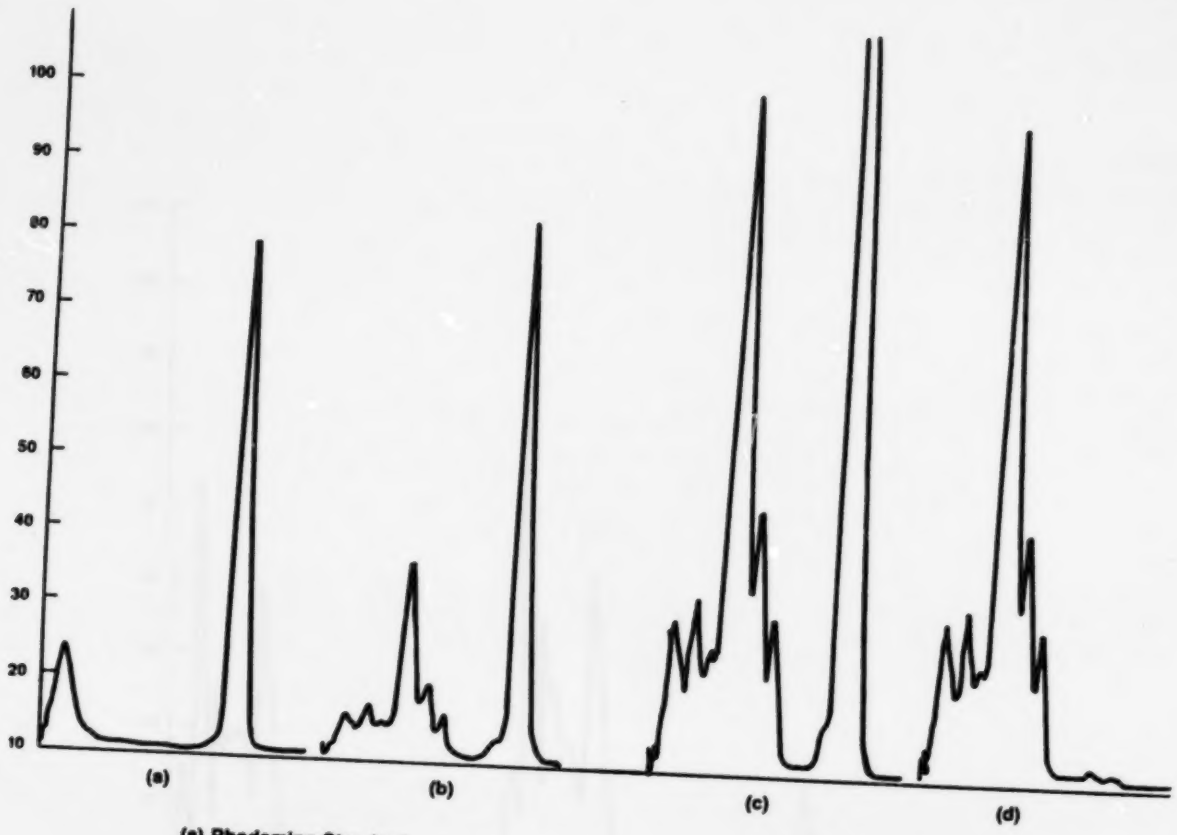

Figure 10. SEFS fingerprint of effluent.

TABLE II. RESULTS OF GRAB SAMPLES TAKEN PRE AND POST DOSING OF EFFLUENT WITH RHODAMINE WT.

Sample	Description	Measured Rhodamine WT Concentration
11685	Effluent Grab Pre-Rhodamine Dosing	0.05 ppb
11686	Effluent Grab Post-Dosing	5.03 ppb
11687	Field Blank	0.02 ppb (None Detected)
11688	Effluent Grab Pre-Dosing	1.11
11689	Effluent Grab Post-Dosing	210.00 ppb
11690	Trip Blank	0.02 ppb (None Detected)

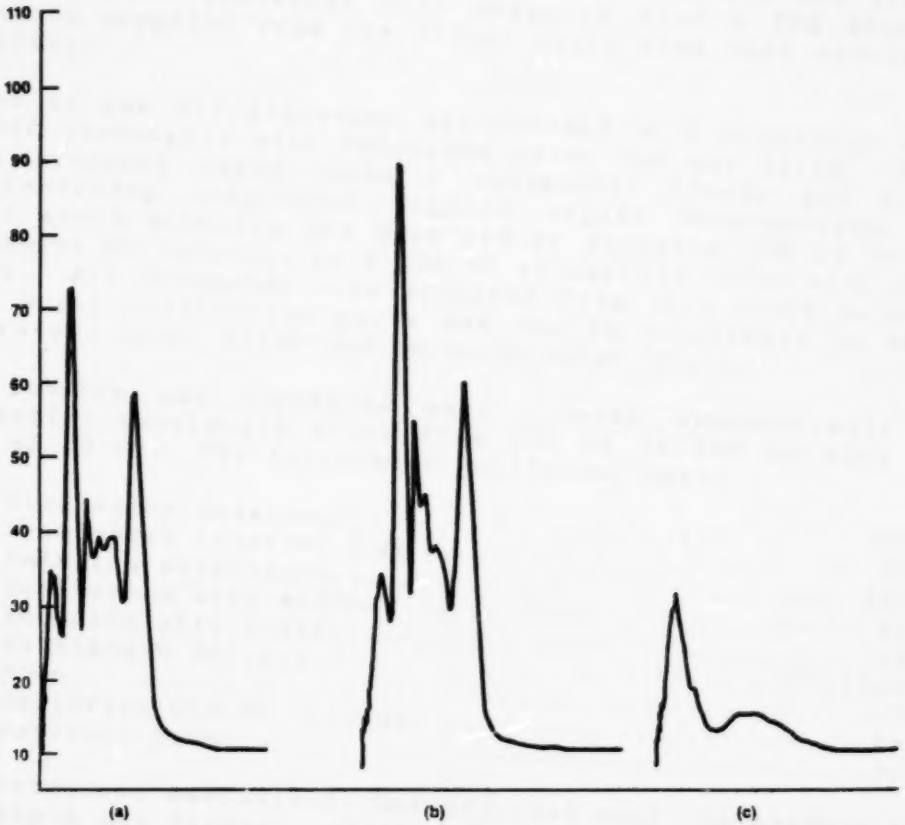

Figure 11.

SEFS Fingerprints of "Winding River Park" Water Samples.
(a) Grab 44202
(b) Grab 44203 taken downstream of effluent source
(c) Grab 44205 taken upstream of effluent source (Control Sample)

PHASE II

The primary objective in Phase II was to evaluate the use of SEFS to monitor for Rhodamine Dye Tracer in effluent and ocean water samples. The standards were prepared from a 20% Rhodamine WT solution supplied from the actual stock drum used on-site at the facility.

Prior to use all glassware was cleaned with chromerge solution, rinsed thoroughly with deionized water and air dired. Standards were prepared using class A volumetric flasks and Scientific Manufacturing Industries digital adjust micropetters. A 200 ug/ml stock solution was prepared by dilution 100 ul of the 20% Rhodamine WT solution in a 100 ml volumetric flask with deionized water. All standards were prepared from this stock solution. A five point calibration curve was run in triplicate as well as a laboratory water blank and an ocean water blank.

The samples and standards were scanned synchronously on the excitation wavelength drive from 200 nm to 640 nm with a delta (Δ) of 20 nm. The instrument conditions were:

Excitation wavelength	200 nm
Wavelength interval (Δ)	20 nm
Emission wavelength	220 nm
Excitation slit width	10 nm
Emission slit width	10 nm
Wavelength drive	Excitation
Mode	Dual
Amplifier dynode voltage	Ratio
Recorder power	Servo

The instrument sensitivity was adjusted near the maximum settings to achieve the highest possible detection limits of Phodamine WT where necessary.

Figure 12 illustrates the type of SEF spectra obtained for Rhodamine WT of Surf Samples collected by the N.J.DEP along the New Jersey Coast near the source of effluent discharge. These specific analyses were performed to determine the occasional impingement of the oceanic discharge plume on the beach. Calculated concentrations of Rhodamine WT in Figure 12 were 0.05-0.08 ppb.

Figure 13 illustrates an SEF spectrum of an effluent sample dosed with Rhodamine WT. Table 2 summarized the results of grab samples taken pre and post dosing of effluent with Rhodamine at the source of discharge. Note that Rhodamine was apparently

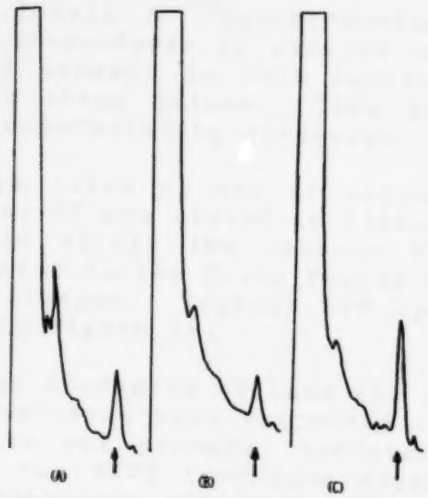

FIGURE 12. SEF SPECTRA FOR QUANTITATION OF RHODAMINE WT IN SURF SAMPLES. ARROW INDICATES RHODAMINE. SAMPLE C SPIKED WITH RHODAMINE WT.

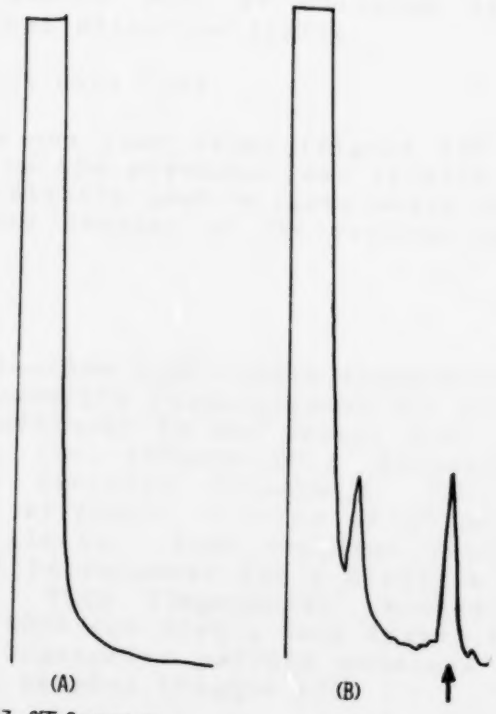

FIGURE 13. SEF SPECTRA OF
(A) FIELD BLANK AND
(B) EFFLUENT GRAB POST DOSING WITH RHODAMINE. ARROW INDICATES RHODAMINE. NOTE THAT SAMPLE WAS DILUTED 1 TO 2,500 TO AVOID CONCENTRATION QUENCHING EFFECTS.

detected at low levels in "Pre-Rhodamine Dosed" samples. Dye constituents and by-products of similar composition to Rhodamine (that are usually present in this particular type of effluent) could account for these values. This effluent is reported to emanate from dye manufacturing processes.

Results of samples taken at sea at various depths and dilution ratios of Rhodamine WT are listed in Table 3. These samples were a vertical profile within the oceanic discharge plume. These ratios were estimated in the field during sampling using a Turner Flow Through Fluorimeter. Typical SEF spectra of these samples are demonstrated in Figure 14.

Detection limits of Rhodamine WT that are practically achieveable in actual sample matrices were estimated to be about .001 ppb (1 ppt). Lower limits are probably achieveable by direct in-situ measurement using the SEFS technique depending on interferences from fluorescing compounds indigenous to ocean water matrices.

PHASE III

The objective in this phase was to continue to evaluate the use of SEFS for monitoring industrial effluent by obtaining spectra from the same source over an extended time interval and to determine practical detection limits.

SPECTRA COMPARISON OVER TIME

In samples taken one year later (Figure 15) the SEF fingerprint remains similar to the previous year (Figure 7). There has been a shift in the relative peak heights which may indicate a slight change in effluent content of the various compounds produced by the facility.

DETECTION LIMIT

The practical detection limit where industrial effluent can still be detected and possibly fingerprinted was determined by serially diluting sample effluent in sea water, i.e., 1 to 5, 1 to 10, 1 to 50, 1 to 100, etc. (Figure 16). Although a delta of 20 nm provides a more detailed fingerprint for samples containing higher levels of effluent, a delta of 80 nm yields significant lower detection limits. Some spectral resolution is lost but sufficient detail is retained for a distinct fingerprint pattern (see Figure 9). This fingerprint pattern is retained to a dilution of 1 to 4000 for Grab 1 (see figure 10). The subsequent utility of the fingerprint pattern obtained at delta 80 nm was confirmed in surf samples (Figure 12).

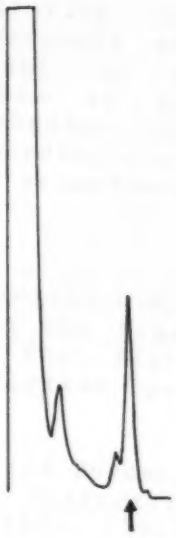

FIGURE 14. TYPICAL SEFS OF OCEANIC SAMPLE NO. PR-1 (ARROW INDICATES RHODAMINE WT)

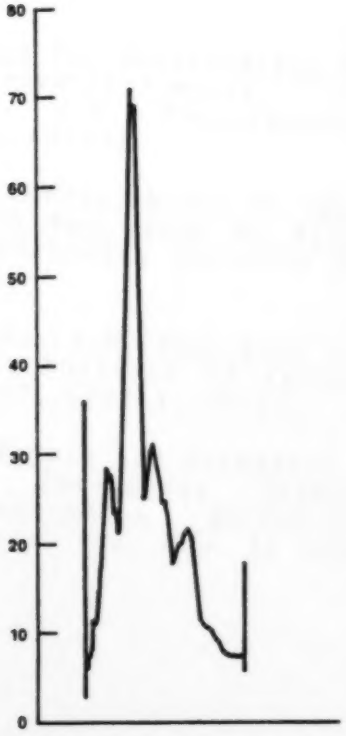

Figure 15. 24 hour effluent composite sampled April 1987

CONCLUSION

A sensitive monitoring procedure was developed based on fluorescence measurements which can reliably quantitative and fingerprint effluent at concentrations ppb levels. The procedure makes use of synchronous excitation fluorescence spectroscopy to monitor the fluorescent properties of the effluent. This procedure can be used to monitor the discharge of actual effluents in groundwater, river water and sea water.

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